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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

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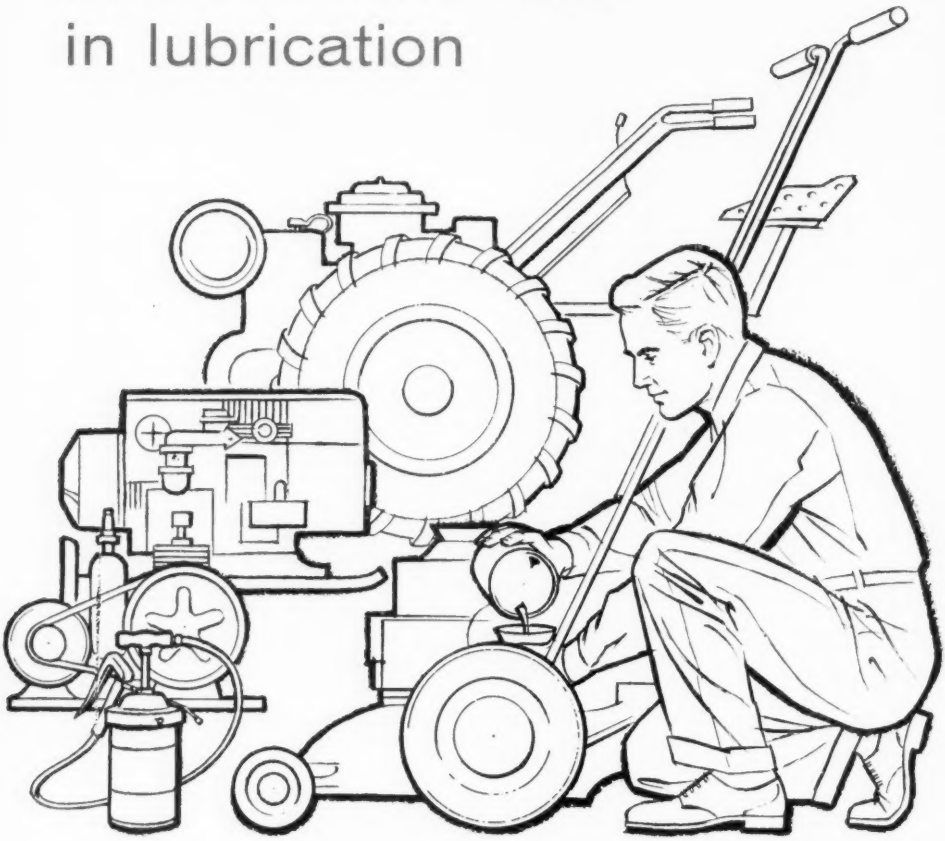

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LUBRICATION

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Power In a Small Package

POWER used by the individual is probably the most significant measure of any civilization. With only his own physical energy available, early man was forced to live the precarious roaming existence of a hunter, barely able to fill his own belly. The capture and training of animals added considerably to his own puny power, increased his mobility and his effectiveness as a hunter, and eventually assisted in accomplishing his tremendous conversion to agriculture with its characteristic responsibility and stability. Only then could man discover and begin to use other and inanimate sources of energy like wind and water power, wood, coal, gas, electricity, liquid petroleum and now uranium.

The ideal source of energy should (1) cost little, (2) be capable of storage without depreciation until required, (3) be easily and quickly converted into other forms, (4) have high energy density, i.e., high power to weight (or bulk) ratio and (5) be readily transportable without ties to any fixed location. Judged by these standards, all but one of the eight energy sources have considerable disadvantages. For example, wind and water power are not only dependent in quantity and time on fickle nature but are inconveniently located and are not transportable. Wood, coal and gas are heavy or bulky in comparison to their modest energy content. Electricity is not portable, not readily stored in quantity and is tied firmly to the end of its transmission lines. Uranium is neither available for ordinary usage nor inexpensive: within the limitations of current technology its tremendous power potential is not readily and safely converted into small amounts of portable power. Thus liquid petroleum, and especially gasoline is the only one that meets all the five criteria for the ideal source of energy. In fact, gasoline's unique properties together with its widespread availability are directly responsible for the development of the gasoline engine and especially the small, powerful, light-weight gasoline engine of 11 or less horsepower — "Power In a Small Package" — which is the subject of this article.

Pioneers of today's huge small-engine industry were the early horseless buggies, inboard marine engines as early as 1886, Ole Evinrude's outboard marine engine of 1906, and stationary engines used largely on farms to power water pumps, churns, washing machines, and lighting generators. Though the expansion of transmission lines has enabled electric motors to take over many of these older *stationary* applications, the small gasoline engine has entered numerous entirely new fields where its rugged dependability, high power, and unfettered maneuverability are unchallenged.

TYPES OF ENGINES

Two quite different types of engines — the "two-cycle" and the "four-cycle" — are in use. Both have a carburetor, one or more cylinders with spark plugs energized and timed by a flywheel magneto, and a pull-rope or other starting device. Either type may use any number of cylinders, through one or at most two cylinders is usual for the small engine. Either type may use either a horizontal or vertical crank-

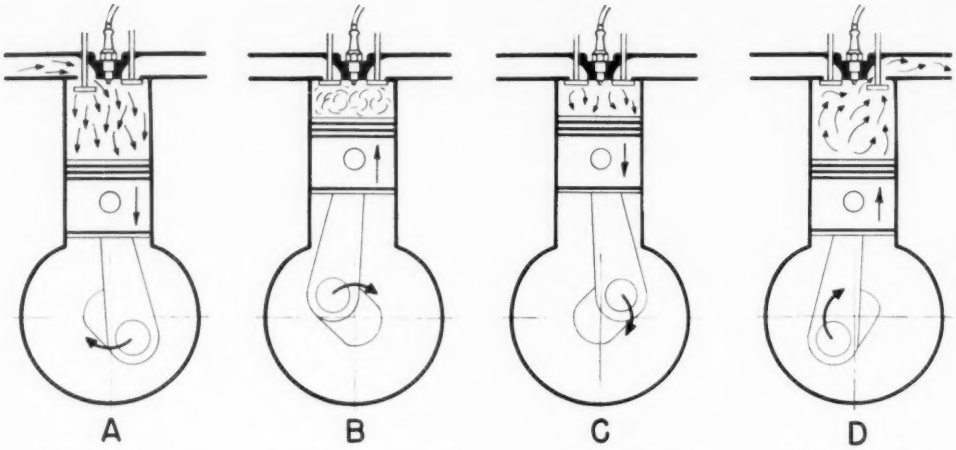


Figure 1A — Intake | Figure 1B — Compression | Figure 1C — Power | Figure 1D — Exhaust

Figure 1 — Operating principle of the four-stroke cycle gasoline engine.

shaft. Where minimum weight is particularly important, both types are likely to be air-cooled, and the requisite flywheel-fan and shrouding conceals other details. While positive recognition of engine type may be difficult, it is highly essential that they be differentiated. Preparation and handling methods of fuel and lubricant for the two engine types are so different that any confusion is ruinous. Too many two-cycle engines have been ruined by attempting to treat them as four-cycles and vice versa. An examination and understanding of the operating principles of the two types is therefore mandatory.

The Four-Cycle Engine

The four-cycle engine, more properly called the "four-*stroke* cycle" is the older of the two engine types since it was proposed by Beau de Rochas early in the nineteenth century. For our purposes a "cycle" is defined as a complete stroke or movement of the piston in one direction which corresponds to one-half revolution of the crankshaft. Each cylinder of the usual four-cycle engine contains at least two "poppet" valves — an intake and an exhaust — which are kept closed by strong springs and opened at a precise moment by means of cams on a camshaft which is geared to and operates at half the speed of the crankshaft. Referring to Figure 1 (which schematically diagrams a single cylinder with horizontal crankshaft) and to the following description, it will be seen that the four-cycle engine requires four strokes or two complete crankshaft revolutions to produce one power stroke. The other three strokes are merely preparatory to the power stroke.

Intake Stroke — The intake valve (to the reader's left) is opened while the piston moves downward, sucking a mixture of gasoline and air from the carburetor into the cylinder. This is shown in Figure 1-A.

Compression Stroke — The intake valve is closed and the piston moves upward compressing the mixture into the combustion chamber. Near the upper end of this stroke, Figure 1-B, the spark plug is timed to ignite the mixture.

Power Stroke — The mixture burns, Figure 1-C, generating a high pressure which forces the piston downward and produces useful power. Near the lower end of this stroke the exhaust valve is opened to release cylinder pressure and to allow most of the burned gases to discharge into the exhaust manifold.

Exhaust Stroke—The exhaust valve remains open, Figure 1-D, while the piston moves upward and pushes out most of the remaining burned gases in preparation for the next intake stroke.

The four-cycle engine is usually lubricated by a definite quantity of oil in its crankcase which is either pumped under pressure to the bearing surfaces or is splashed onto them when the connecting rod and crankthrow cheeks intercept the oil surface. Thus the amount of oil entering the combustion chamber and consequent carbon deposits are limited by the oil-control ability of the piston rings.

Because of its precise valve action and complete separation of functions among its four operating strokes, the four-cycle engine is best suited to those applications where (1) the very minimum weight is not important, (2) the best attainable fuel economy is desired, (3) excellent idling, part throttle

and governor operation is desirable and (4) highest torque at low and medium speeds is required.

The Two-Cycle Engine

The two-cycle or two-*stroke* cycle engine was developed by Dugald Clerk in 1878, and is conspicuous by its ingenious simplicity. As can be seen in the schematic diagrams of Figure 2, this engine functions by utilizing three openings or "ports" in its cylinder wall which are covered and uncovered by the piston. Thus there are no valves of the ordinary type, no camshaft and no gearing. Since the intake and exhaust functions are performed simultaneously and inseparably during only a part of one stroke, the two-cycle engine gives a power stroke every crankshaft revolution as follows:

(1) The upward stroke of piston "F" compresses a mixture of gasoline vapor, air, *and droplets of lubricating oil* into the combustion chamber "D". The same piston stroke also creates a partial vacuum in crankcase "B" which sucks in the next mixture charge through the carburetor and port "A". Near the upper end of the stroke, spark plug "G" is timed to ignite the compressed mixture.

(2) The resulting combustion pressure forces piston "F" downward on its power stroke, closes intake port "A" and compresses the new mixture charge in crankcase "B". Near the lower end of this stroke, the piston uncovers exhaust port "E" which releases cylinder pressure and discharges most of the burned gases. Further piston movement then uncovers the "bypass" or "transfer" port "C" which allows the compressed new mixture in crankcase "B" to flow upward into combustion chamber "D" where it pushes most of the remaining burned gases out exhaust port "E". The head of piston "F" is usually shaped to direct the flow of new mixture upward into the cylinder and to sweep out the maximum amount of exhaust gas with minimum intermingling and loss of new mixture out the exhaust port.

The two-cycle engine is lubricated by carefully measuring, adding, *and thoroughly mixing* a small quantity of special lubricating oil into the gasoline itself. When this gasoline-oil mixture passes through the carburetor, the gasoline is largely vaporized but the oil is broken up into tiny droplets or oil fog which lubricates everything it touches as it makes its single passage through the engine.

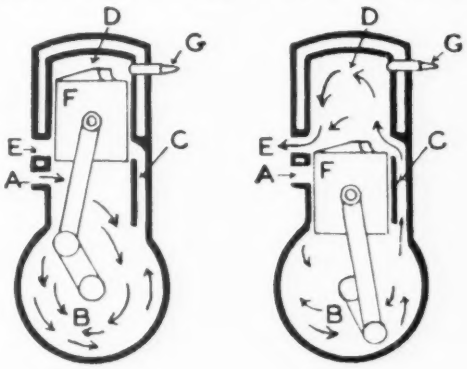
Theoretically at least, the two-cycle engine should produce twice as much power as a four-cycle of the same cylinder bore and stroke and operating speed since the two-cycle has twice as many power strokes. Actually this ideal is approached but never fully attained. But because of its unique operating principles the two-cycle engine is best suited to those applications where (1) maximum power with minimum weight and volume is required, (2) power is needed at high and reasonably constant engine operating speeds.

Engine Type Recognition

If the manufacturer's name plate fails to mention "two-cycle" or "four-cycle," his operating instructions may mention oil in gasoline (which would identify it as a two-cycle) or he might specify either a crankcase capacity or a crankcase oil level which would apply only to a four-cycle type. If none of this information is available, engine type is positively determined by disconnecting or shorting out the spark plug, then putting a chalk mark on the rope starter flange, rotary lawnmower cutter blade or other part attached directly to the engine crankshaft. Then crank the engine slowly. If the resistance due to compression is felt *every* revolution, the engine is a two-cycle. Resistance only on alternate revolutions would indicate a four-cycle (and no resistance at all would mean that a general overhaul was much overdue).

Engine Speed Control

Before leaving the discussion of small engine types, it may be profitable to discuss briefly the problem of engine speed control. Once started, the engine, either two- or four-stroke, relies on only two factors to determine its speed. The first is the load under which the engine is operating and the second is the amount of throttle opening. If the load is light, it may be possible to open the throttle wide enough for the engine to overspeed and destroy itself. If the converse occurs, too little throttle opening and too great a load, the engine merely stalls



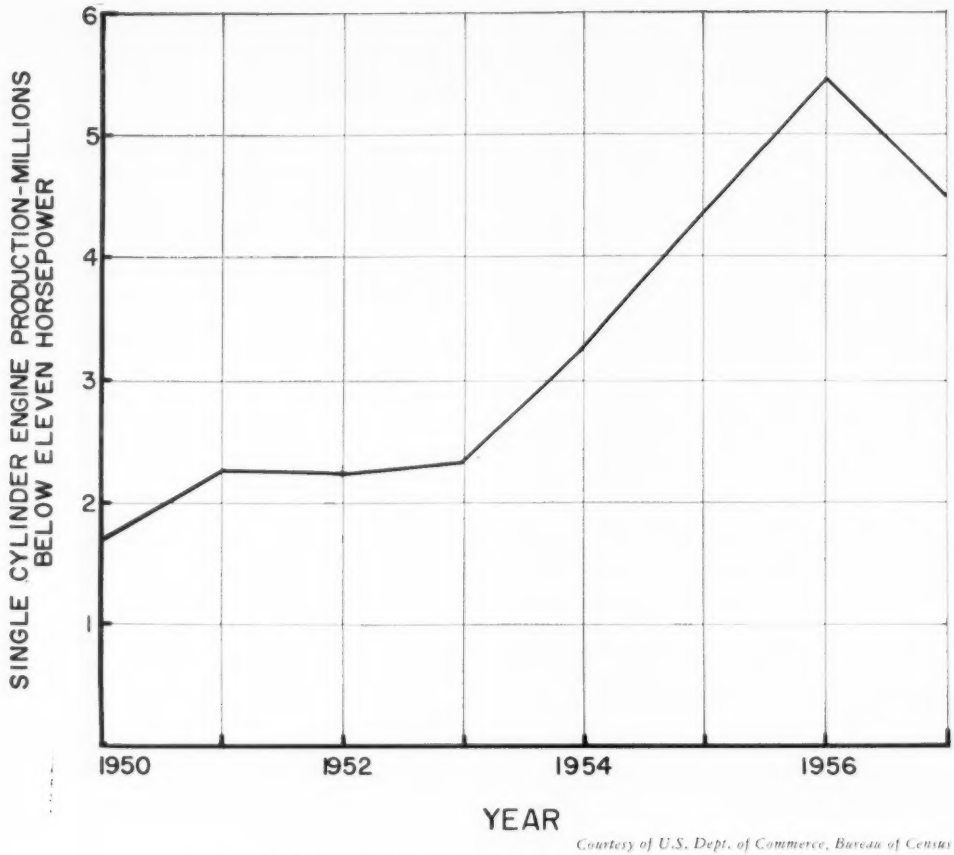
A

Cylinder: Compression and Ignition
Crankcase: Intake

B

Cylinder: Intake and Exhaust
Crankcase: Compression

Figure 2 — Operating principle of the two-stroke cycle engine.



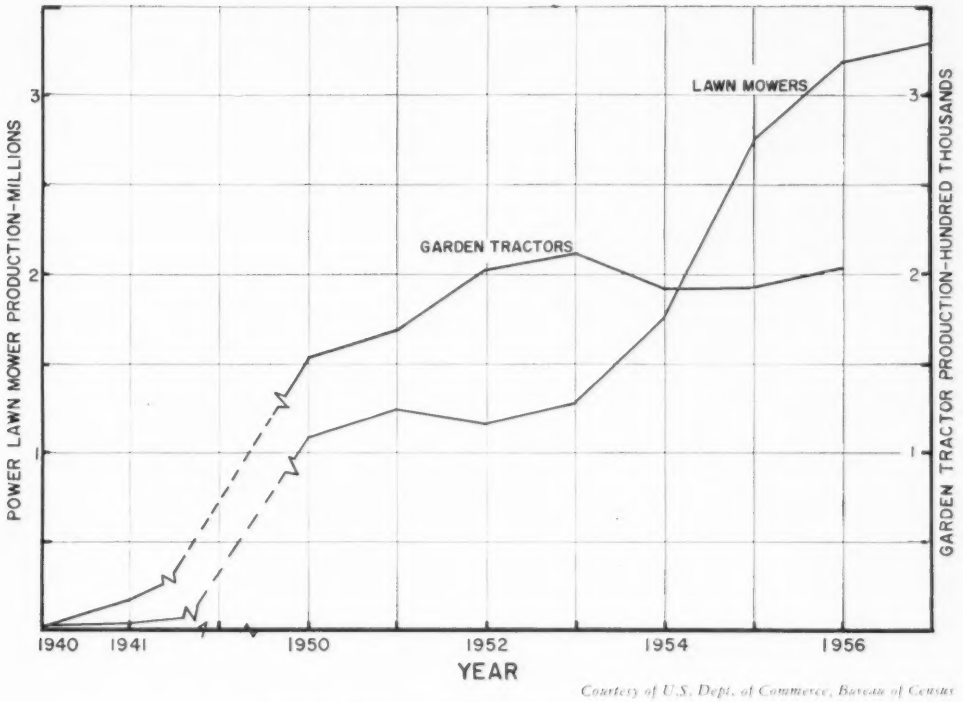
Courtesy of U.S. Dept. of Commerce, Bureau of Census

Figure 3 — Production of single cylinder engines of less than eleven horsepower.

and usually no damage is done. Of these two cases, the first is the more serious. For this reason many manufacturers restrict the flow of incoming air and gasoline mixture to the engine by use of a small carburetor venturi. This, in effect, limits the top "no-load" speed and keeps it within safe limits. Most manufacturers do not connect the speed control directly to the throttle since such a system would permit an undesirable drop in engine speed as the load is applied. Instead, a governor is incorporated in the throttle system which senses the drop in engine speed due to an increase in load and opens the throttle so as to keep the speed constant. Most of the governors use the air flow blowing on a moveable vane to indicate engine speed. As the engine speed drops, the airflow decreases and the governor opens the throttle to compensate. It is obvious that should the cooling duct become clogged with debris, it not only would permit engine overheating, but render the governor useless. On larger engines, the speed is controlled by a centrifugal governor which uses the rotational speed of moving weights to control the throttle opening.

ENGINE APPLICATIONS

The phenomenal growth in the production and use of the small engine has been occasioned by several factors. Among these is the trend toward a more suburban type of living. This has broadened the market for motorized lawn and gardening accessories far beyond the prewar requirements. A second factor is the increasing cost of labor both for home gardening chores and for industrial production. Initial capital outlay for tools of this type, lawn and garden care, building, transportation, and materials handling processes all benefit greatly from the increased use of small engines. The extent to which production of these engines has increased is dramatically indicated in Figure 3. In 1956, the annual production of these engines approached five



Courtesy of U.S. Dept. of Commerce, Bureau of Census

Figure 4 — Production of lawnmowers and garden tractors.

and one-half million units and thus nearly equalled the automobile production for that year. Figure 4 indicates that a majority of this increase has resulted from the greater use of this type of power in small, home type lawn mowers and garden tractors.

Lawn and Garden Equipment

As shown in Figure 4, one of the most popular uses of the small engine is to power lawn mowers equipped with either a two- or four-cycle engine. Due to economics of manufacture and production, these units are now within the reach of a majority of suburban and country dwellers. Two types of small lawn mowers are the rotary type and the reel type. Rotary mowers are probably the most popular since their simplicity of construction lends itself to low cost. One factor which has accelerated the use of this type is the development of the vertical shaft engine. Engines of this type are available in either two- or four-cycle designs. A typical four-cycle vertical shaft motor is shown in Figure 5. A two-cycle version of the vertical shaft engine is shown in Figure 6. When this type of unit is installed in a complete mower, the resultant tool is small, light-weight, and economical. This type of mower is shown in Figure 7.

While generally more costly and heavier, the reel type of mower is still popular. This type is

Courtesy of Briggs & Stratton Corp.

Figure 5 — Single cylinder air-cooled four-cycle gasoline engine with vertical crankshaft.

Courtesy of Lauson-Power Products Engine Division, Tecumseh Products Co.

Figure 6 — Single cylinder air-cooled two-cycle gasoline engine with vertical crankshaft.

illustrated in Figure 8. With enlarged house lot sizes and consequently more grass to cut, many home owners are now using the riding type of mower as illustrated in Figure 9

Garden tractors have also become very popular.

Courtesy of Lawn-Boy Division, Outboard Marine Corp.

Figure 7 — Rotary type lawn mower.

Courtesy of Motor Wheel Corp.

Figure 8 — Reel type self-propelled lawn mower.

The reasons for this may be found in the increased leisure time available for gardening and the gradually lowering prices of these labor savers. Units of this type shown in Figure 10 usually can be equipped with a large variety of accessories. Tillers, graders, harrows, weeders, cultivators, sprayers, and sickle-bar mowers are available as accessories. In addition to this array, some tractors can be equipped with saws for cutting brush and small trees.

Auxiliary generators, usually powered by two-cycle engines, are also available for either standby service, in case of power failure, or for the powering of electrically-driven devices such as chain saws, circular saws for on-the-site carpentry, hedge clippers, etc.

Industrial Equipment

Aside from the obvious benefits to the home owner which are now available due to the use of small engine power, many industries also benefit greatly from this type of equipment. Manhole ventilating blowers, auxiliary power generators, auxiliary starting engines for large construction equipment, small cement mixers, trailer truck refrigeration compressors, and many other devices are all powered by small engines. Another widespread use

Courtesy of Toro Manufacturing Corp.

Figure 9 — Reel type self-propelled riding lawn mower.

Courtesy of Gravely Tractors, Inc.

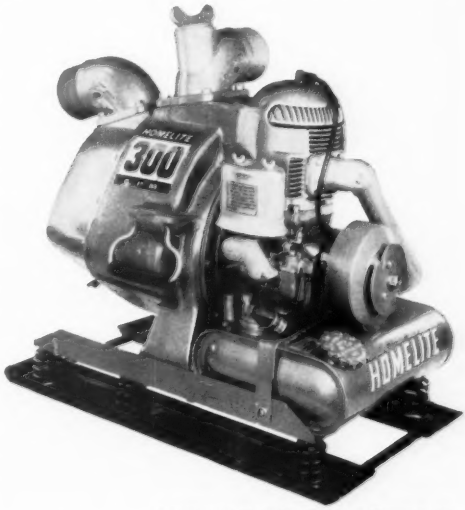
Figure 10 — Garden tractor with rotary plow attachment.

of small engines is in drainage and irrigation. A two-cycle engine and pump unit of this type are shown in Figure 11. In addition to the above units, there are many industries which use these small engines to effect direct savings in labor. Two outstanding examples of this are the widespread use of the chain saw in the lumber industry. Without the advent of powerful lightweight engines, much of the sawing would still be done by hand. A typical chain saw powered by a two-cycle engine is shown in Figure 12. Another major labor saving is effected by the recent introduction of powered materials handling equipment such as is shown in Figure 13. Here, concrete handling buggies are powered by a four-cycle gasoline engine which allows one man to do the work of several with less effort.

Special Applications and New Features

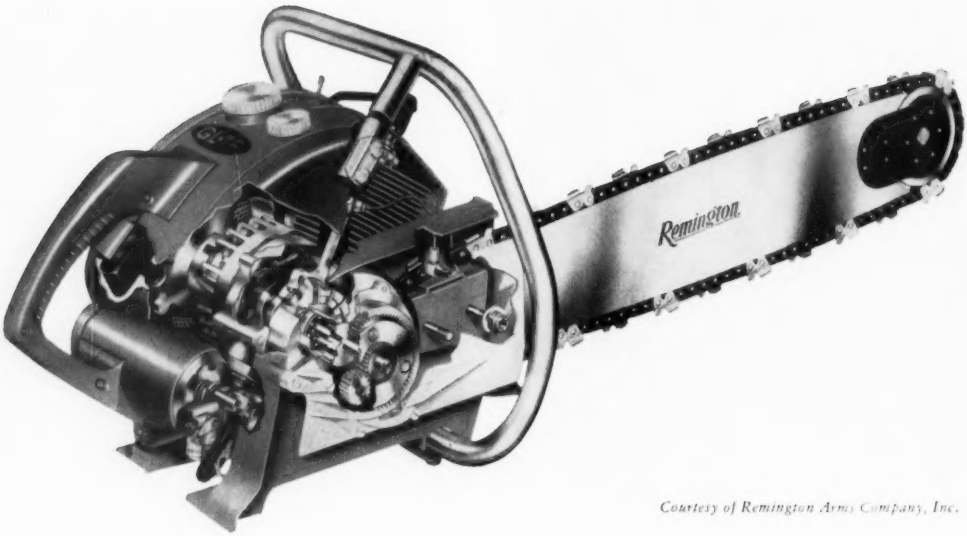
To add to the popularity of those units equipped with small engines, many special uses have been developed by the engine and equipment manufacturers. Among these are the specialized design applications such as the post hole digger or earth drill shown in Figure 14, and the portable small brush cutter shown in Figure 15. In these instances, because light weight coupled with maximum power is desired, two-cycle engines are used.

Additional widespread usage of these small engines has been cultivated by the continued develop-



Courtesy of Homelite Division, Textron, Inc.

Figure 11 — Two-cycle engine-driven water pump.



Courtesy of Remington Arms Company, Inc.

Figure 12 — Two-cycle engine-driven chain saw.

ment work conducted by many manufacturers toward lowering costs and making their equipment easier to operate. Among the most recent innovations is the use of die-cast aluminum rather than cast iron engines so as to reduce weight. The die casting process permits the manufacturer to use permanent reusable molds which in turn lowers costs. In addition, die-cast metals usually are cast more accurately and therefore require less final machining which further reduces costs. Aside from these obvious advantages, the light weight allows the use of these engines in many applications where the previous weight penalty made the use of a gasoline engine prohibitive.

Other convenient features are the innovation of multiple engine controls whereby all the engine operations are controlled from a single point. Recoil starting devices which eliminate the use of starting ropes are now almost standard equipment on all engines and eliminate the sometimes tire-

Courtesy of Creative Metals Corp.

Figure 13 — Concrete handling power buggy.

Courtesy of McCulloch Corp.

Figure 14 — Earth drill or post hole digger.

some starting chore wherein the rope had to be rewound before each starting attempt was made. Electric starters are also used.

LUBRICATION AND MAINTENANCE OF SMALL ENGINE POWERED EQUIPMENT

As with any investment, it is desirable to obtain maximum life utility for the amount invested. In the case of tools which are powered with small engines, the utility is a direct function of the amount of care which is given to its maintenance. No facet of engine and tool maintenance is more important than the lubrication practices followed. Much of the wear and general deterioration can be minimized through the use of quality lubricants applied in accordance with the manufacturers' recommendations and the specified relubrication periods.

Engine Lubrication

As mentioned previously, it is extremely important that the lubrication requirements of each type of engine whether it be two- or four-stroke, be adequately met. In the case of two-cycle engines, the oil is mixed with the gasoline and then fed through the carburetor to the engine crankcase. The crankcase does not contain any oil supply and is essentially dry. In the crankcase the gasoline evaporates and continues on to the cylinder where it is burned. Oil is also carried through to the combustion chamber but on the way it provides lubrication for the cylinder and piston assembly, the crankshaft and connecting rod bearings. It is important that the oil be of the correct viscosity and type *and be thoroughly and completely mixed with the gasoline prior to use.*

The quantity of oil mixed with the fuel for use in two-cycle engines varies with the manufacturer. It may range from between ⅓ to 1½ pints of oil to a gallon of gasoline. The average is about ½ pint per gallon. During break-in, most manufacturers recommend that this ratio be increased slightly to insure satisfactory operation during this critical period.

Many manufacturers recommend either SAE 30 or 40 viscosity grades of oil depending on the ambient temperature encountered. In this case the manufacturers' recommendations should be followed.

Since all of the oil added to the gasoline of a two-cycle engine is burned, the type of oil used is extremely important. It is obvious from the above discussion that the oil must meet two diametrically opposed criteria. It must resist oxidation (burning) in the high temperature portion of the engine while it is acting as a lubricant. This is especially true in the piston ring area where accumulated deposits can seriously affect engine performance. It also must burn completely once it has entered the combustion chamber. A majority of the difficulties which occur with two-cycle engines can be traced to the use of either too much oil or oil of

Courtesy of Hoffco, Inc.

Figure 15 — Brush cutter.

Figure 16 — Deleterious effects of improper oil on a two-cycle engine piston.

the wrong type. In the former case, the manufacturer's recommendation should be followed. In the latter case, a good quality two-cycle motor oil is essential so as to prevent excessive piston ring belt deposits, combustion chamber deposits, and possible spark plug fouling. Figure 16 shows the type and amount of deposits which can be expected on a two-cycle engine piston when an improper lubricant is used. Also shown in Figure 17 is a piston operated with the correct type of oil. Note the cleaner piston skirt and ring belt area and the fewer combustion deposits on the piston crown.

In the case of the four-cycle engines, the lubrication requirements are somewhat different. In this design, all of the oil is kept in the engine crankcase and does not mix with the fuel to be burned. It is usually circulated by means of a pump and gravity system, a full pressure pump system or by the splash system. Since these oils do not normally enter the combustion chamber, automotive type engine oils are suitable. In these engines, the viscosity of the oil used is somewhat more important than in the case of the two-cycle engine. The grade recommended is usually varied depending on the ambient temperature expected. The recommendations of the manufacturer should be followed in the selection of the correct viscosity grade of oil. Oil changes should be made at regular intervals in accordance with the instruction booklet, and more frequently if operating in extremely hot or dusty conditions.

Engine Fuels

For years it has been a popular misconception that small engines must use "White Gasoline." However, developments in the marine field (as discussed in the June, 1958 issue of magazine LUBRICATION) and in the small engine field have made this requirement obsolete. Starting difficulties may often be attributable to the use of gasolines which are not seasonally adjusted to compensate for the particular temperatures encountered. These problems can be greatly reduced or eliminated through the use of commercially available automotive gasoline which is refinery fresh. The suppliers of reputable brands of automotive gasoline vary the characteristics of the gasoline frequently so as to compensate for seasonal changes in temperature and insure the best possible starting characteristics under all conditions. Marine White types of gasoline, while they will do no damage if used in small engines, are increasingly difficult to obtain and are not usually seasonally adjusted to insure best starting.

Engine Storage

Before the discussion turns to the other lubrication requirements of the equipment powered by these small engines, it might be well to consider the special problems associated with the engine which is used at infrequent intervals. This is often the case with equipment used around the home and garden. The snow plow gets little use in the summer and the garden tractor is used but infrequently during the winter months. In these instances where the engine is to be out of service for a period longer than two or three weeks, a few special precautions will insure longer life and easier starting when the equipment is needed.

The major cause of deterioration in storage is due to rusting of the cylinder and piston rings. This is particular critical in four-cycle engines where the oil is not mixed with the fuel. It is accentuated by the operator who accelerates the engine and then cuts off the spark while the engine is operating at

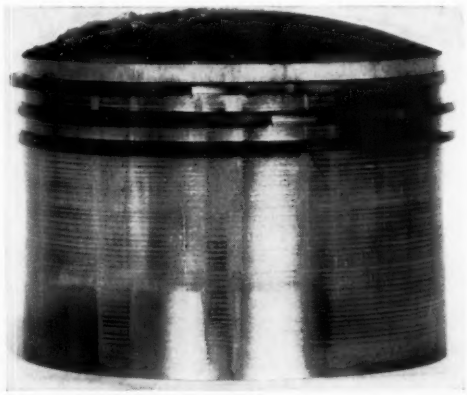


Figure 17 — Protective effects of a good oil on a two-cycle engine piston.

Courtesy of Clinton Engines Corp.

Figure 18 — Single cylinder air-cooled four-cycle horizontal crank shaft engine with manual clutch.

high speed This allows the incoming gasoline to wash any possible oil film from the cylinder walls and permits the rapid onset of destructive rusting. When the engine is to be stored, the spark plug should be removed and a small amount of engine oil added to the cylinder through the hole. Because an automotive type "heavy duty" oil with API Service Designation of DG or DM usually has exceptional rust prevention characteristics, it is best for this purpose. Such an oil is also recommended for the crankcases of *four*-cycle engines. The engine should then be rotated a few times by hand with the spark plug not installed. The plug should then be reinstalled and the engine brought to top dead center on the compression stroke. This procedure applies to both two- and four-stroke engines. The gasoline tank should be drained and, in the case of four-cycle engines, the crankcase oil should be changed. This simple procedure will provide good protection against the harmful effects of rusting. To reactivate, refill the fuel tanks with fresh gasoline, install a clean or new spark plug, and start in the normal manner.

LUBRICATION OF ACCESSORIES

Aside from the engine, much of the powered equipment also has other points which require lubrication. Driving chains and gears, reduction gearing, ball and roller bearings, and many other points require attention to insure trouble-free performance.

Drive Gear Lubrication

Those units where the drive is through a gear box of some type usually specify that engine oil of the correct viscosity grade be used as the lubricant. In those cases where the transmitted loads are higher, special gear lubricants are prescribed. These special lubricants may be either straight mineral gear lubricants of fairly high viscosity or additive type gear lubricants. In any event, the type and viscosity of lubricant recommended by the manufacturer should be used. All reputable oil suppliers manufacture and have available either straight mineral or additive type gear oils of good quality suitable for use in equipment of this type.

Chain Drive Lubrication

Enclosed drive chains, as shown in Figure 8, usually run in an oil bath which requires replenishment from time to time. These cases must also be drained and refilled to the required level at regular intervals. If an oil bath is not used, frequent lubrication is necessary but cleaning is not required as often as is the case with exposed chains which are discussed below.

Exposed chains should not be overlubricated since the excess oil merely picks up dust and dirt to form an abrasive compound which accelerates chain wear. The chain should be removed, cleaned and relubricated at regular intervals, depending on the severity of service. One method by which this can be done is to soak the chain in kerosine so as to remove old oil and dirt. The chain should then be washed in a clean kerosine so that the kerosine will penetrate the moving parts and remove old oil and dirt from these also. A paint brush is handy for this work. After drying, soak the chain in warm engine oil so that complete penetration of the chain is obtained by the new oil. The chain then should be wiped reasonably dry with a clean dry cloth and reinstalled. Occasional reoiling with an oil can will be satisfactory until cleaning is again required.

In the case of chain saws, the foregoing does not apply. These units operate at fairly high speeds and under heavy loads. The chain is guided throughout its entire travel by a steel track and must be lubricated. This is evident by referring to Figure 12. Many chain saws provide an automatic lubricator which supplies a correctly metered amount of engine oil to the chain while it is running. Others merely have a hand operated pump by which the chain is lubricated with engine oil either during operation or before each new cut. If lubrication of this part is neglected, heavy chain and guide bar wear will result and costly replacements will be necessary.

Belt Drives

Many home type and some industrial units which use small gasoline engines, transmit the drive by means of one or more "Vee" belts. While belts do not provide a positive "no slip" drive as do chains,

they are useful since they provide an inexpensive means of transmitting engine power to the wheels. This type of drive is illustrated in Figure 9. Aside from being an economical means of transmitting power, the vee belt also serves the function of a clutch since, when it is loosened, it will not transmit power and when tightened it will. A simple pulley arrangement can be used to tighten or loosen the belt as desired.

These belts are usually made of rubber and cloth vulcanized together. Since they are rubber, they may be adversely affected by oil, grease or gasoline which may spill on them. Care should be exercised to avoid this since, aside from the possibility of belt damage, excessive slippage may result from the presence of these materials.

Wheel and Support Bearings

Wheel bearings and support bearings may be of the ball or roller type. Those which are not lubricated by either the engine oil, or the gear case oil, usually are sealed for life and require no lubrication. In those instances where grease fittings are supplied, a good grade of ball and roller bearing grease should be used and at regular intervals. Bearings of this type do not require large quantities of grease and care should be exercised not to overlubricate.

A unit of this type is shown in Figure 18. This engine is fitted with a hand-operated clutch. The clutch throw-out or release bearing must be periodically lubricated. Overlubrication would cause grease to be thrown onto the clutch friction surfaces which would render the clutch useless.

SUMMARY

From the foregoing it can be seen that there is an increasing use of small engines particularly in equipment designed for yard and garden use. It is important to differentiate between two- and four-cycle engines in order to insure proper engine lubrication. Engine, accessory and general tool life can be greatly increased through the use of the correct grade of lubricants having adequate quality.

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